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Wolfson et al.

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(54) **PROSTHESIS FOR SIMULATING NATURAL KINEMATICS**

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USPC 623/18.11, 16.11, 20.14, 20.15, 623/20.28–20.31, 23.39

See application file for complete search history.

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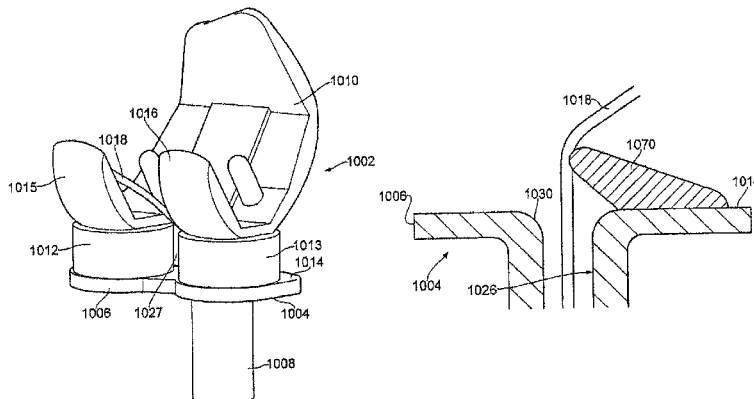
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(57) **ABSTRACT**

A bearing component **2** for a joint replacement prosthesis comprises a first bearing element **4**; a second bearing element **6**, and a linking element **8**, operatively connecting the first and second bearing elements **4**, **6** and permitting relative motion there between. The flexible linking element **8** prevents dislocation of mobile bearings in a total knee replacement prosthesis. The invention also relates to a bridging element which retains the linking element **8** with some play, which acts as a ligament support **2051**, and which causes a deflection of the line of action of a ligament **1018**. A joint replacement prosthesis is also disclosed comprising a biasing element **1140** or a tensioning element **1220** operatively coupled to the artificial ligament **1018**. The biasing element **1140** or tensioning element **1220** may be housed in the stem of a tibia tray **1006**.

13 Claims, 17 Drawing Sheets



Related U.S. Application Data

continuation of application No. 13/923,779, filed on Jun. 21, 2013, said application No. 13/923,768 is a continuation of application No. 12/740,998, filed as application No. PCT/GB2008/003677 on Oct. 31, 2008, now Pat. No. 8,470,048.

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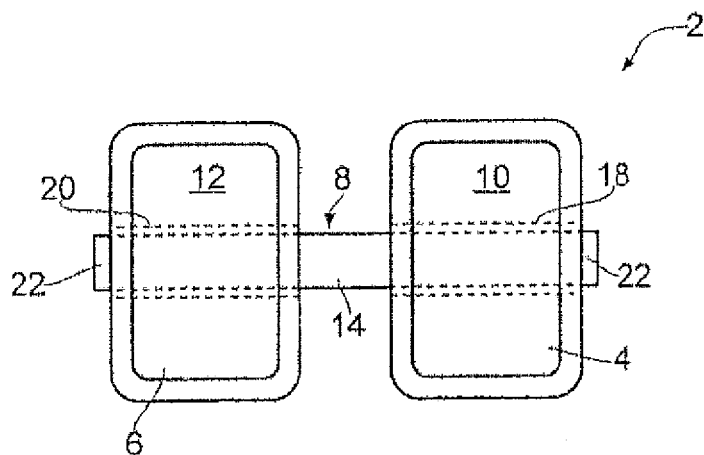


FIG. 1

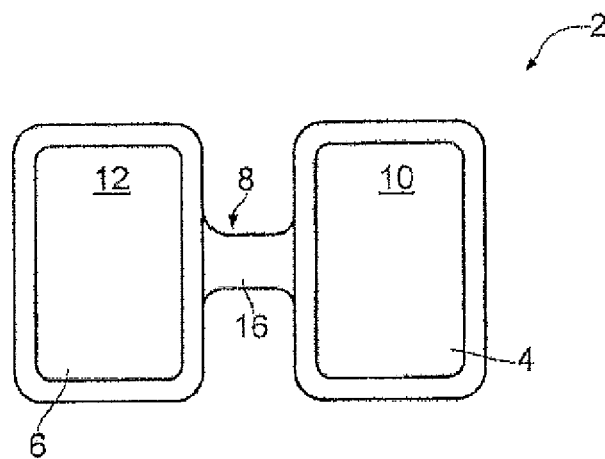


FIG. 2

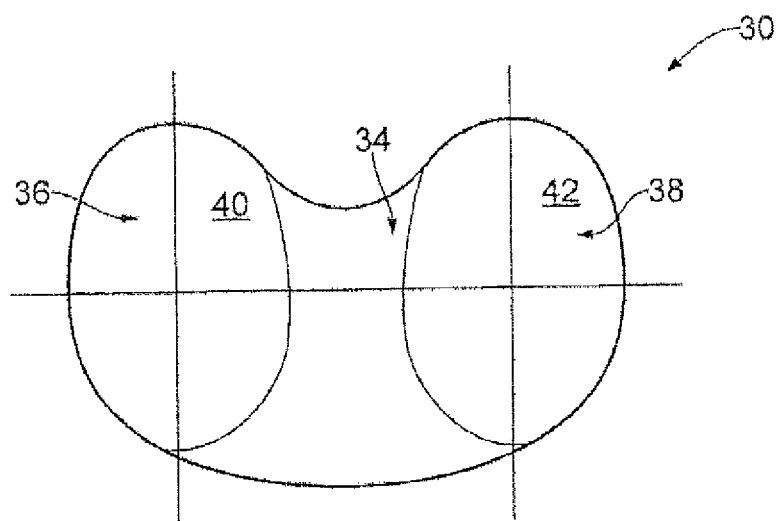


FIG. 3

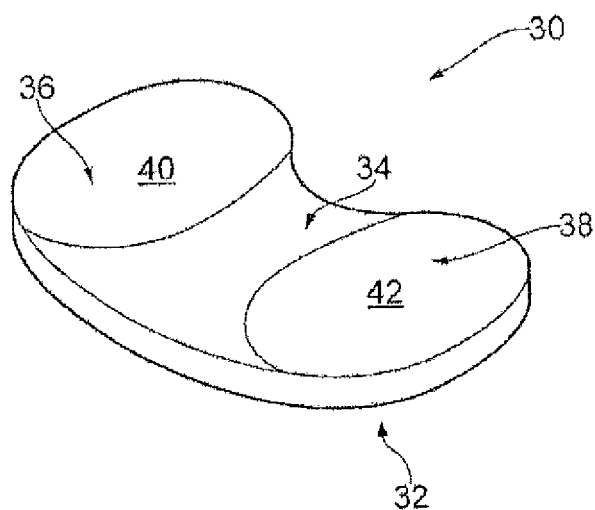


FIG. 4

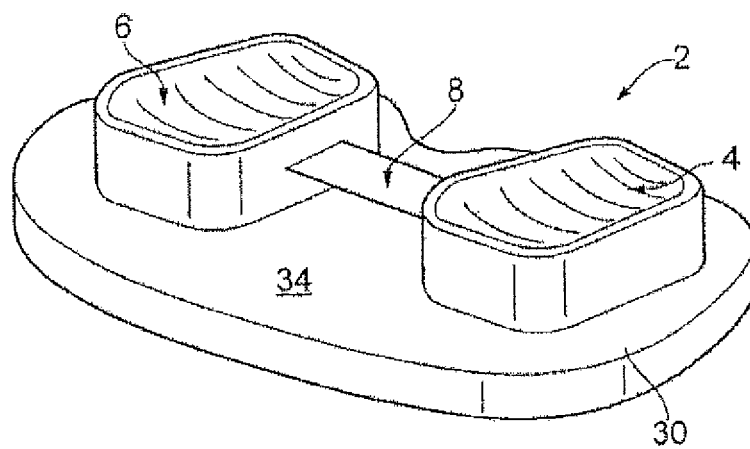


FIG. 5

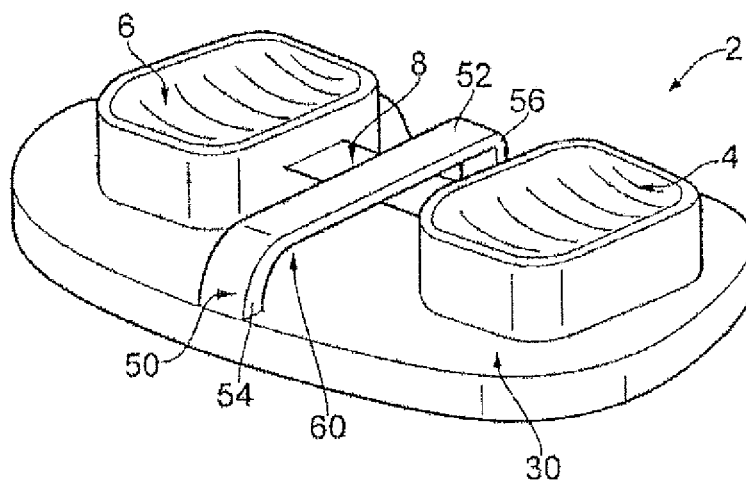


FIG. 6

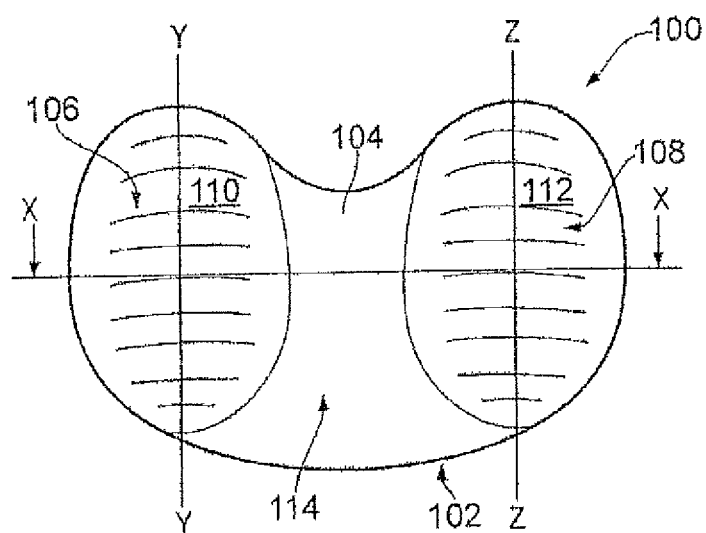
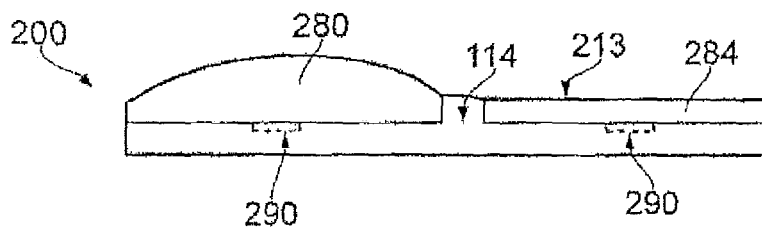
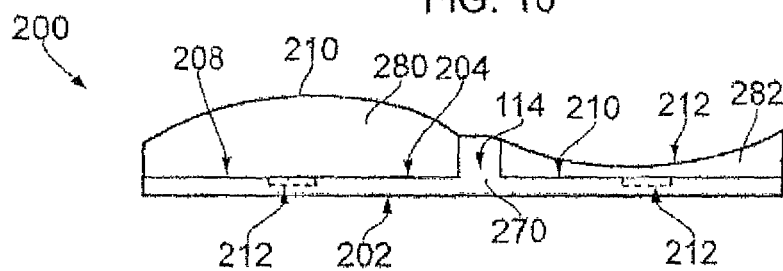
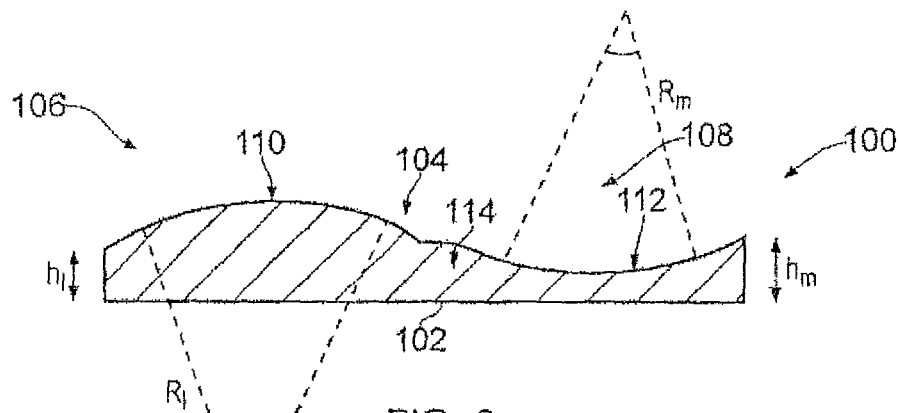


FIG. 7



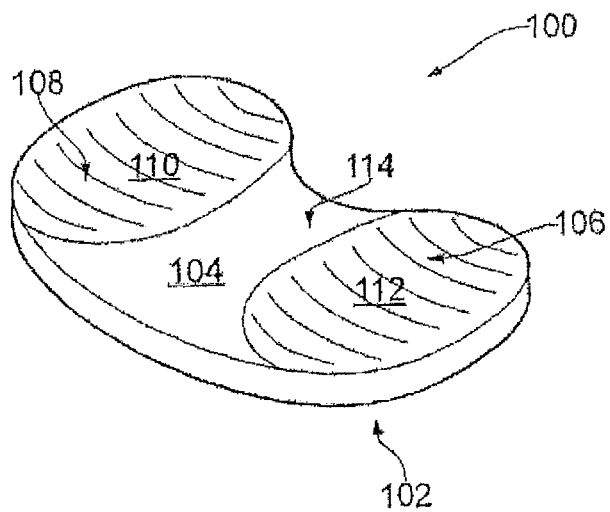


FIG. 11

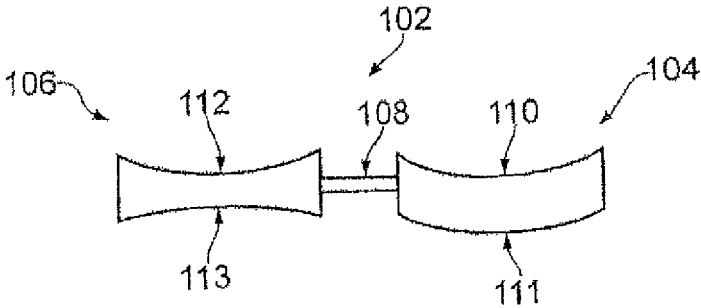


FIG. 14

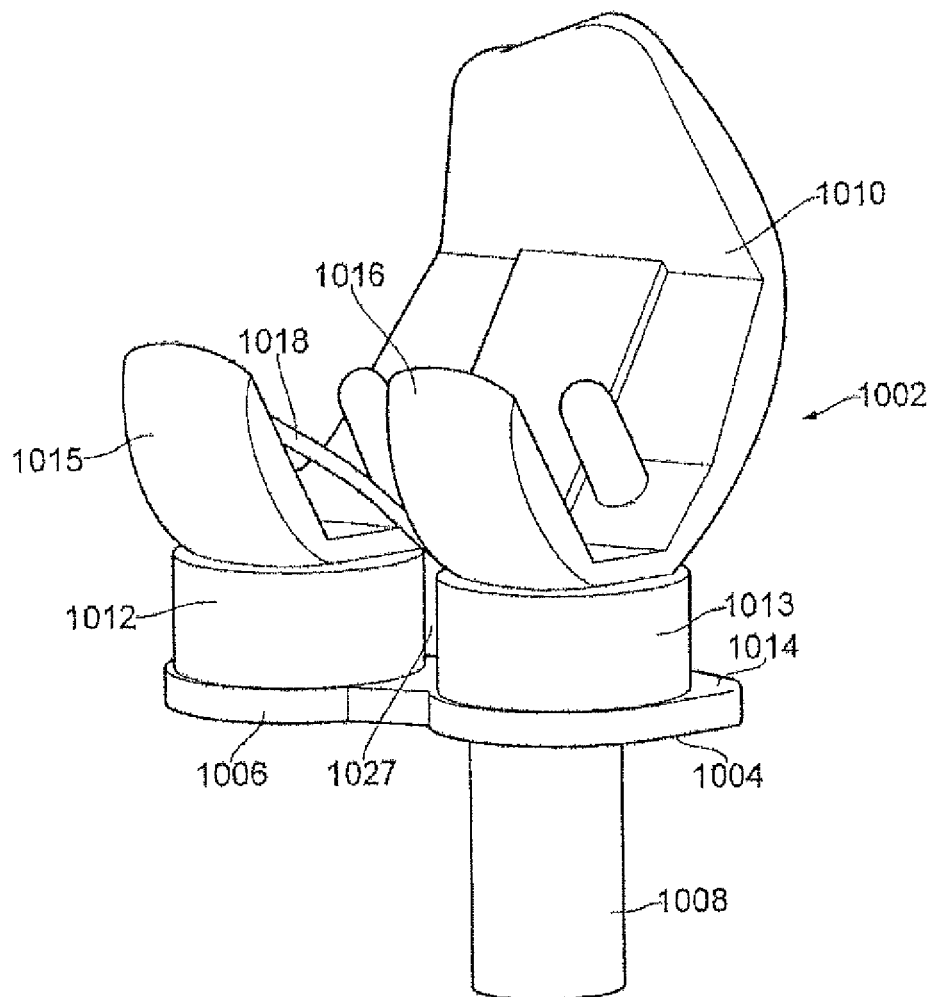


FIG. 15

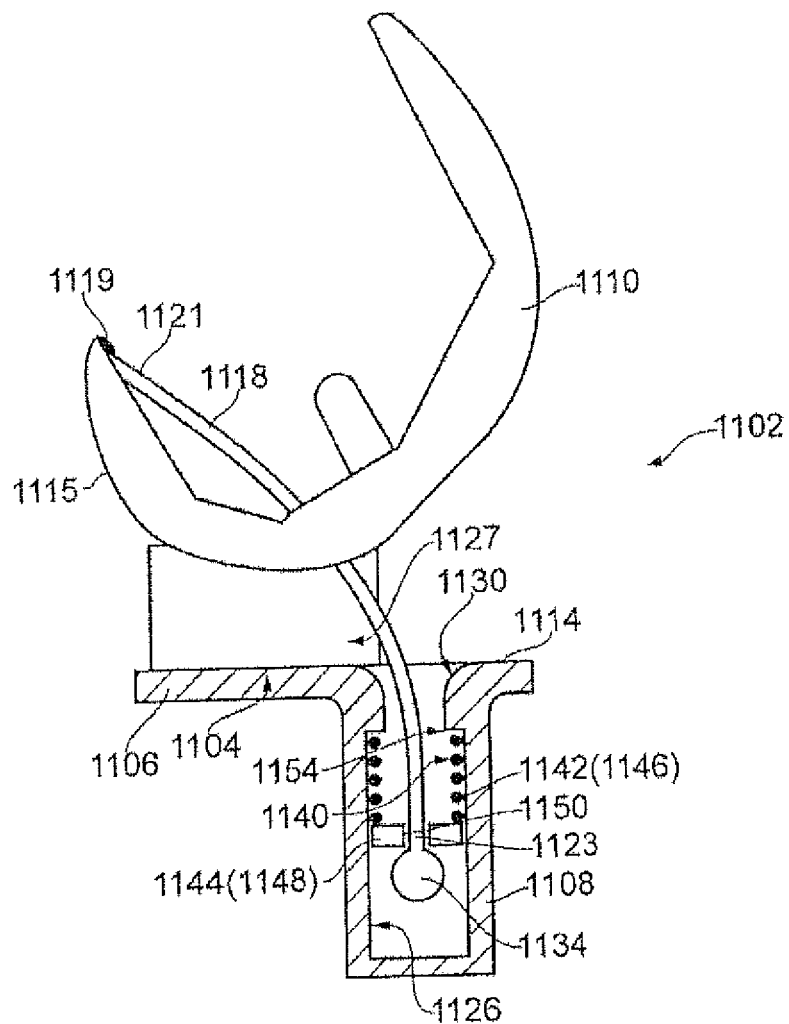


FIG. 16

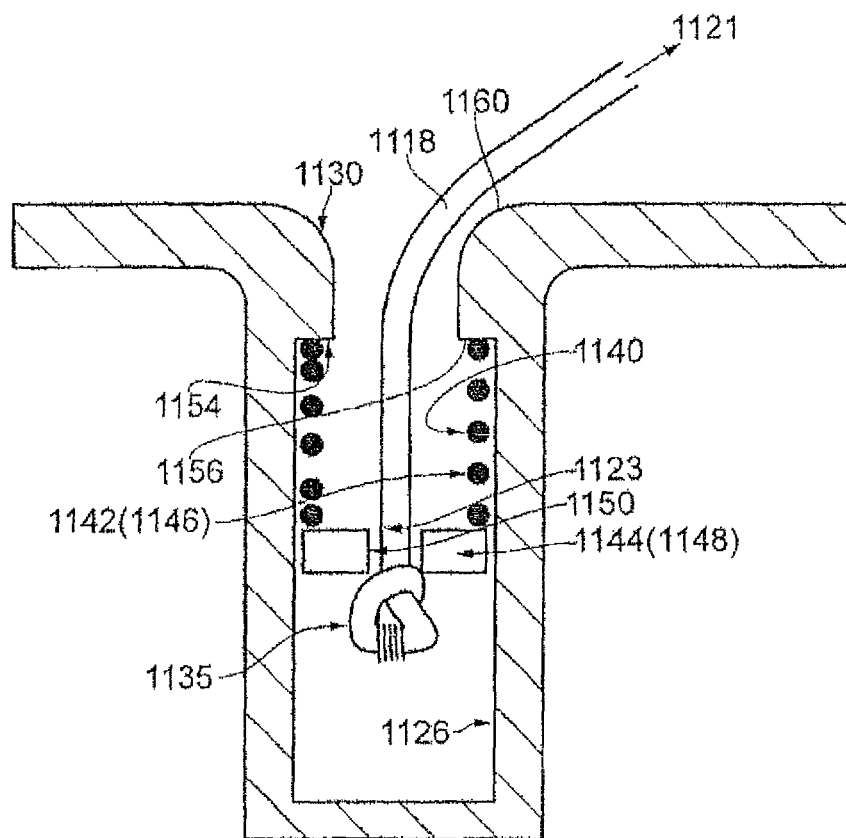


FIG. 17

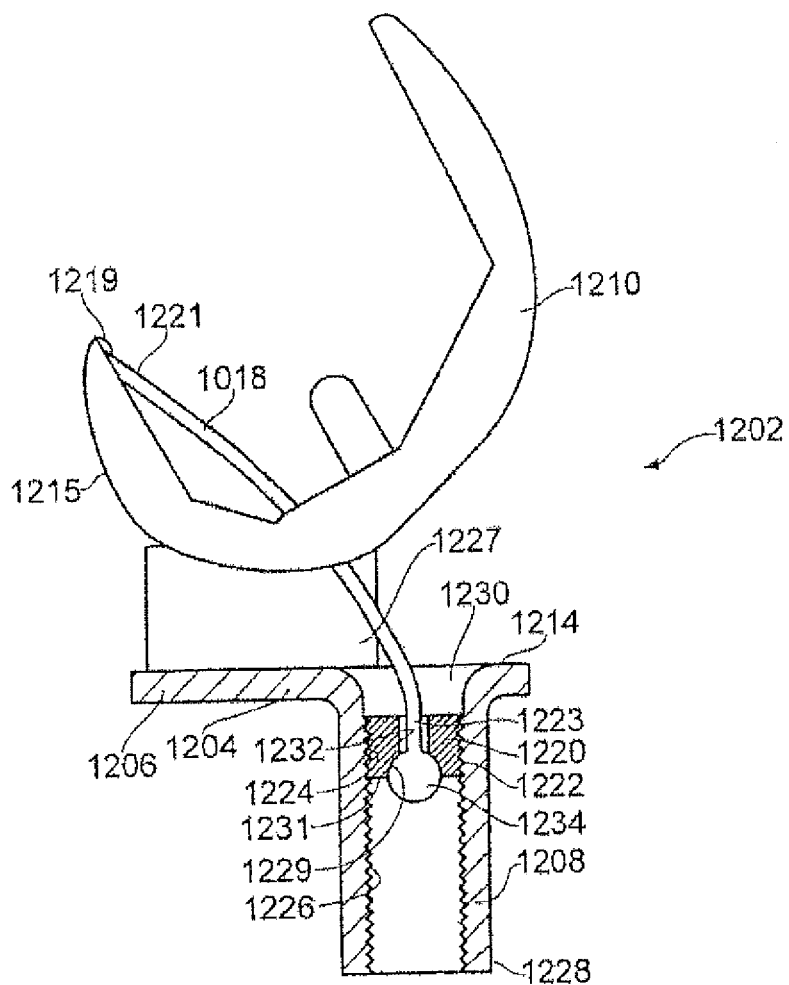


FIG. 18

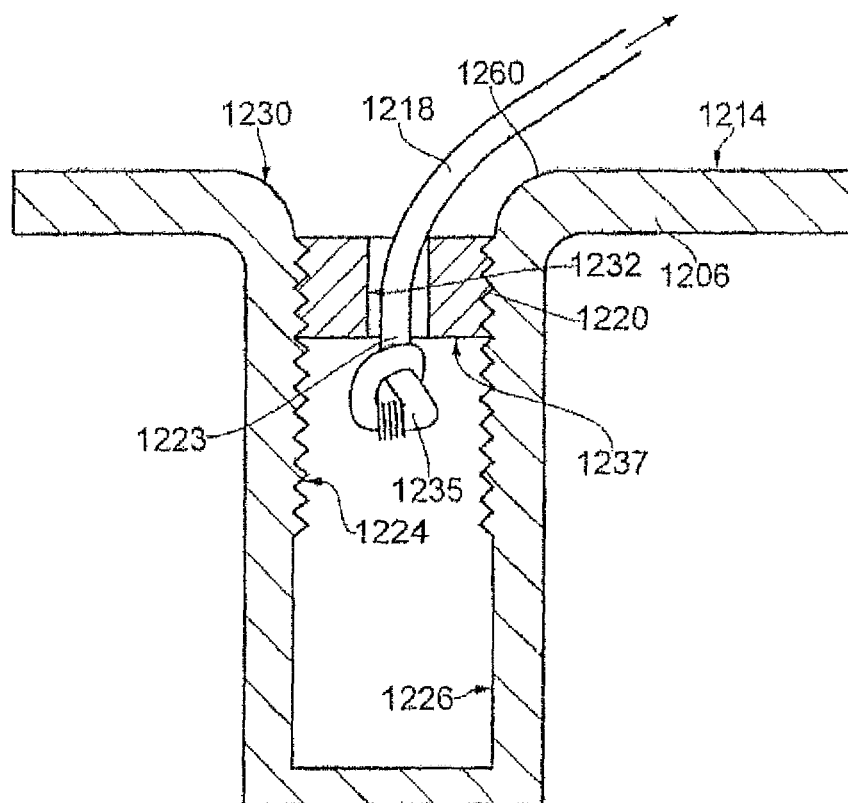


FIG. 19

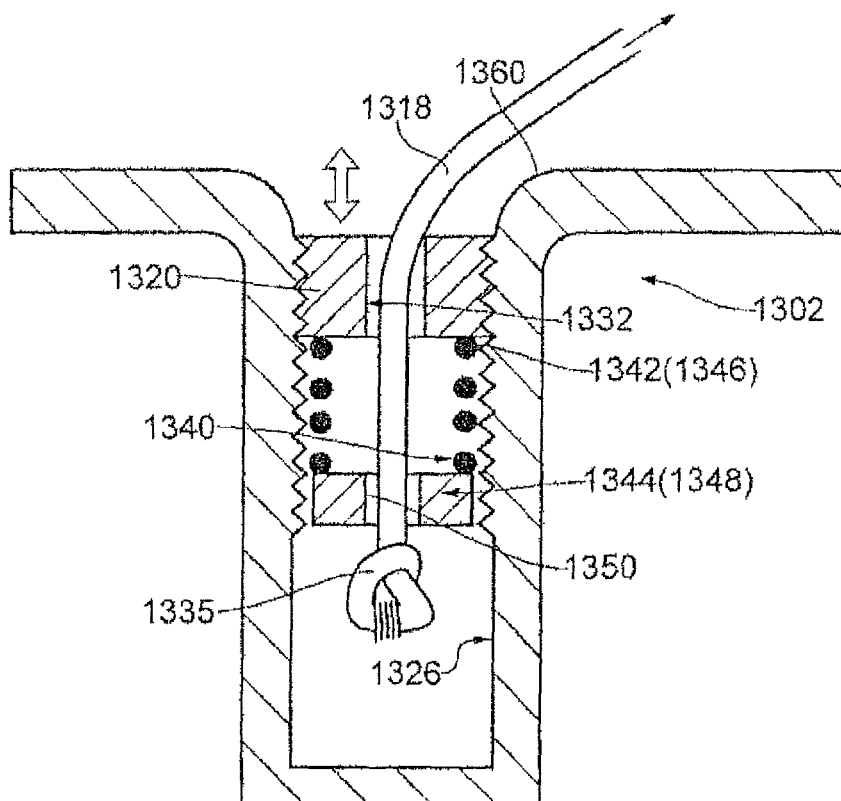


FIG. 20

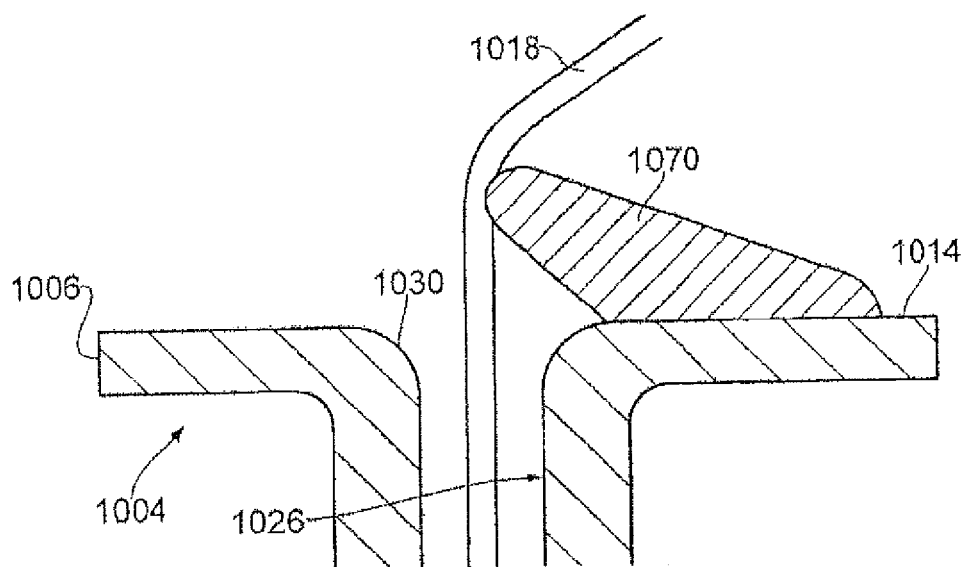


FIG. 21

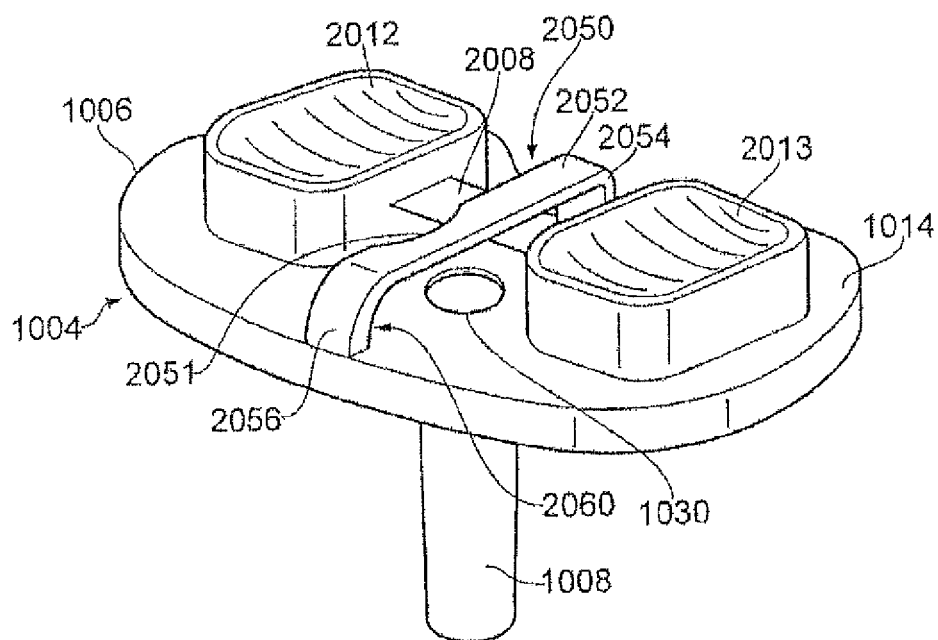


FIG. 22

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PROSTHESIS FOR SIMULATING NATURAL KINEMATICS**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of: (1.) U.S. patent application Ser. No. 13/923,768 filed on Jun. 21, 2013, and (2.) U.S. patent application Ser. No. 13/923,779 filed on Jun. 21, 2013, which is a continuation of U.S. patent application Ser. No. 12/740,998 filed Nov. 23, 2010, now U.S. Pat. No. 8,470,048 issued on Jun. 25, 2013, which is a 371 U.S. National Phase Application based on International Application Number PCT/GB2008/003677 filed Oct. 31, 2008, which claims the benefit of: (1.) Great Britain Patent Application No. 0721610.4 filed Nov. 2, 2007, and (2.) Great Britain Patent Application No. 0805917.2 filed Apr. 1, 2008. The entire disclosures of each of the above applications are incorporated herein by reference.

FIELD

The present disclosure relates to a prosthesis for simulating natural kinematics and particularly, but not exclusively, relates to a bearing component and a prosthetic ligament for use in a total knee replacement prosthesis.

BACKGROUND

This section provides background information related to the present disclosure which is not necessarily prior art.

Joint replacement prostheses commonly comprise two bone engaging components that articulate via a bearing component. In a total knee replacement prosthesis, the bone engaging components are a femoral component, comprising an anterior surface with patella track and two femoral condyles, and a tibia component, comprising a substantially planar surface or tray and a post, keel or other stabilizing feature. The femoral and tibia components articulate via a bearing component mounted on the tray of the tibial component. The bearing component may be fully or partially fixed with respect to the tibial component, and commonly comprises a single piece of high density polyethylene.

In order to more closely replicate the natural kinematics of the knee, it is desirable for a total knee replacement prosthesis to facilitate a combination of rolling, rotational and translational movement between the femoral and tibial components of the prosthesis. This can be achieved in part by employing a "mobile" bearing component, having some freedom of movement relative to the tibial component on which it is supported.

SUMMARY

This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

According to a first aspect, there is provided a bearing component for a joint replacement prosthesis, the component comprising: a first bearing element; a second bearing element, and a linking element, operatively connecting the first and second bearing elements and permitting relative motion there between.

The linking element provides a physical connection between the two bearing elements while still allowing relative motion between the two bearing elements. The linking element thus prevents dislocation of either bearing

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element in the event of distraction in either compartment of the prosthesis in which the bearing element is employed.

The linking element may be flexible and may be elastic or resilient. Such a linking element thus affords a greater range of relative motion between the two bearing elements

The first and second bearing elements and the linking element may be integrally formed. The linking element may comprise a polyethylene membrane.

Alternatively, the linking element may comprise a fabric or polyester cord.

Respective ends of the linking element may be moulded into the first and second bearing elements. The linking element may extend into and through bores that may extend at least partially through the bearing elements.

According to another aspect, there is provided a joint replacement prosthesis comprising first and second bone engaging components that articulate via the bearing component.

The prosthesis may be a knee replacement prosthesis, the first bone engaging component comprising a femoral component and the second bone engaging component comprising a tibial component.

The bearing component may be supported on the tibial component such that relative motion between the tibial component and first and second bearing elements is enabled.

The articulation between the femoral component and the first and second bearing elements may be at least partially spherical.

The tibial component may comprise at least one tray, on which the bearing component is supported, and a retaining element that extends across the tray, between the first and second bearing elements, passing over the linking element. The retaining element may thus prevent dislocation of the entire bearing component in the event of bilateral distraction.

The retaining element may comprise a bridge, under which the linking element of the bearing component passes, such that the bridge limits the extent of relative motion possible between the linking element and the tibial tray.

The retaining element may be removably connected to the tibial tray, thus facilitating assembly of the prosthesis.

The joint replacement prosthesis may further comprise an artificial ligament.

The artificial ligament may extend between and be connected to the tibial and femoral components. The artificial ligament may engage the retaining element during at least part of its range of movement. The retaining element may be adapted to support and/or deflect the artificial ligament and/or to change a line of action of the ligament. For example, the retaining element may comprise a pulley or have a ligament support surface which has a recess or is waisted to align the ligament and to prevent dislocation. The ligament support surface may be curved and/or chamfered and/or polished to reduce wear of the artificial ligament.

The tibial component of the joint replacement prosthesis may comprise first and second bearing surfaces, operable to articulate with the first and second bearing elements of the bearing component, the first bearing surface being convex and the second bearing surface being non-concave.

The second bearing surface may be concave. The convex and concave bearing surfaces may be at least partially spherical.

According to another aspect, there is provided a method of making a bearing component of the present invention comprising direct compression moulding ends of the linking element into the first and second bearing elements.

According to another aspect, there is provided a method of making a bearing component comprising moulding the first and second bearing elements as a single piece and removing material from the area between the first and second bearing components to define the linking element.

According to another aspect, there is provided a flexible linking element for use in preventing dislocation of mobile bearings in a total knee replacement prosthesis.

The flexible linking element may connect first and second mobile bearing elements. Movement of the flexible linking element may be at least partially constrained by a retaining element.

According to another aspect, there is disclosed use of a flexible linking element to prevent dislocation of mobile bearings in a total knee replacement prosthesis.

The flexible linking element may connect first and second mobile bearing elements. Movement of the flexible linking element may be at least partially constrained by a retaining element.

According to another aspect, there is provided a tibial component for a knee replacement prosthesis, the component comprising a lateral compartment having a convex bearing surface and a medial compartment having a non-convex bearing surface. The convex lateral bearing surface provides increased stability to the lateral compartment of the joint, when the tibial component is assembled in a knee replacement prosthesis.

The bearing surface of the medial compartment may be concave. Such a concave medial compartment provides greater stability and facilitates in replicating the natural motion of the knee when the tibial component is assembled in a knee replacement prosthesis, primarily by reducing motion in the medial compartment of the knee. Combining a convex lateral compartment with a concave medial compartment facilitates restoration of the natural motion of the knee.

Alternatively, the bearing surface of the medial compartment may be planar.

The lateral and medial bearing surfaces may be part spherical and the radii of curvature of the lateral and medial bearing surfaces may be substantially the same. The centre of curvature of each bearing surface may be anterior of the anterior/posterior centre line of the bearing surface and on the medial/lateral centre line of the bearing surface.

The lateral and/or medial bearing surfaces may comprise modular surface components, operable to be connected to a tray component to form the tibial component. The modular surface components and tray component may comprise cooperating fittings to facilitate connection and removal of the modular surface components.

According to another aspect, there is provided a kit of parts for a tibial component of a knee prosthesis, the kit comprising a tibial tray and a plurality of surface components, operable to be removably connected to the tray, the surface components each comprising a bearing surface, at least one surface component comprising a convex bearing surface and at least one surface component comprising a concave bearing surface.

According to another aspect, there is provided a knee replacement prosthesis comprising the bearing component and the tibial component.

It is known to implant an artificial ligament to replace a natural ligament which has become damaged. Conventional artificial ligaments are formed from strands or bundles of artificial fibres which may be woven and/or aligned to form a flexible member which is substantially uniform in size and is resilient along its length.

A natural ligament exhibits high strength, toughness and resilience and retains these properties for many years. To date, it has been impossible to match these properties using artificial fibres.

When implanted, artificial ligaments may be attached to existing bone tissue, provided the tissue at the attachment site is relatively intact. However, if surrounding bone tissue is diseased or damaged, it may be necessary to remove both the natural ligament and the adjacent bone tissue and replace them with prosthetic components.

Joint replacement operations commonly result in removal of at least one ligament. The functionality of the ligament is replicated as closely as possible by one or more features of the replacement prosthesis (as for example in the case of a cooperating cam and post in a total knee replacement). However, it has proved extremely difficult to replicate the natural kinematics of a joint without the presence of naturally functioning ligaments. This is particularly evident in the case of the knee joint, which exhibits a complex movement that is highly dependent upon the interaction of ligaments with the articulating areas of bone.

According to another aspect, there is provided a joint replacement prosthesis comprising an artificial ligament, which is adapted to replace a human or animal ligament, and a biasing element operatively coupled to the artificial ligament to control the effective stiffness of the artificial ligament.

The biasing element may have a stiffness approximating that of a natural ligament that is to be replaced. In this manner, the biasing element may assist in replicating the natural characteristics of the joint. The biasing element may have linear or non-linear stiffness characteristics which may be achieved by methods known in the art. The stiffness of the biasing element may be in a range of 3 N/mm to 40 N/mm.

The biasing element may comprise one or more springs and/or one or more elastic or elastomeric members and/or one or more Belleville washers. The biasing element may comprise a cylinder, tube, toroid, cone or loop of elastic or elastomeric material.

The biasing element may be a coil spring and may be a tension spring or a compression spring. Alternatively the biasing element may be a leaf spring. The leaf spring may engage an abutment at a predetermined position in its range of movement to vary the effective stiffness of the spring.

The spring may be conical, so that it provides variable stiffness over its range of movement. It may, for example, be a conical coil spring.

The biasing element may be operatively coupled to the ligament at or near one end only of the ligament. The biasing element may engage the ligament via a bearing component.

According to another aspect, there is provided a joint replacement prosthesis comprising an artificial ligament, which is adapted to replace a human or animal ligament, and a tensioning element operatively coupled to the ligament for applying tension to the ligament.

The tensioning element may be operatively coupled to the ligament at or near one end only of the ligament.

The prosthesis may further comprise a biasing element, which may comprise an elastic element. The biasing element may act between the tensioning element and the ligament. The tensioning element may be coupled to the ligament via the biasing element. The biasing element may engage the ligament via a bearing element.

The biasing element may be formed as in the previous aspect. For example, it may comprise a spring, which may be a compression spring. The spring may be of any form. For

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example it may comprise a coil spring, a leaf spring, a Belleville washer or an elastic or elastomeric member.

The biasing element may have a stiffness approximating that of a natural ligament that is to be replaced. The biasing element may have a linear stiffness characteristic. Alternatively, the biasing element may have a non-linear stiffness characteristic.

The ligament may be coupled to the tensioning element via an attachment means. The attachment means may comprise an enlarged portion that is formed on the ligament and engages the tensioning element. For example, the enlarged portion may comprise a knot tied in the artificial ligament.

The prosthesis may further comprise a bone engaging element for attachment to a bone. The tensioning element may act between the bone engaging element and the artificial ligament.

The tensioning element may be at least partially housed within the bone engaging element. The bone engaging element may comprise a stem, and the tensioning element may be at least partially housed within the stem.

The tensioning element may be adjustable and may be operable to adjust the tension within the ligament. The adjustable tensioning element therefore enables the tension in the ligament to be adjusted in a controlled manner, independently and controllably altering the characteristics of the ligament.

The prosthesis may further comprise adjustment means operable to adjust the tension in the ligament. The tension may be adjusted by adjusting the position of the tensioning element relative to the bone engaging element. Thus tension in the ligament may be altered even after both ligament and bone engaging element have been implanted into a patient.

The adjustment means may comprise a threaded connection between the tensioning element and the bone engaging element. The tensioning element may comprise an external thread and the stem may comprise a corresponding internally threaded bore within which the tensioning element is received.

The tensioning element may be configured to be screwed into or out of the bore to adjust the tension in the ligament.

The tensioning element may be accessed through an opening formed in the bone engaging element.

The prosthesis may further comprise a retaining element for limiting the motion of one or more bearing elements of the prosthesis, the retaining element being adapted to engage an artificial ligament to thereby change a line of action of the ligament.

The prosthesis may comprise only part of a joint replacement prosthesis, which may be a knee replacement prosthesis.

The prosthesis may comprise at least part of a knee replacement prosthesis in which the bone engaging element comprises a tibial component and the artificial ligament comprises a replacement anterior cruciate ligament (ACL).

Artificial ligaments without suitable stiffness characteristics do not balance with the other soft tissue, resulting in abnormal kinematics. By using a ligament with physiological stiffness, there will be mutual respect with the retained soft tissue, allowing the joint to function normally.

The biasing element and/or tensioning element can protect the ligament from excess load. It has been shown that the loads induced in an artificial ligament which is substantially inextensible are far in excess of the ultimate tensile stress of a natural ligament. By allowing just a small amount of extension in the artificial ligament, these loads are reduced and the ligament and its attachment are protected.

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The biasing element and/or tensioning element can enable the tension of the ligament to be balanced with other soft tissues. This eases the implantation of an artificial ligament because fixation can be optimised first before applying tension to a ligament. In embodiments with an adjustable tensioning element and/or with adjustable fixation of the ligament to the femur a single size or limited range of sizes of artificial ligament can be used on any patient. This reduces the inventory requirements for artificial ligaments.

According to another aspect, there is provided a joint replacement prosthesis comprising a bone engaging element having a stem which is adapted to project into a bone, and an artificial ligament, an end of the ligament extending into and being secured within the stem.

The prosthesis may comprise at least part of a joint replacement prosthesis, which may be a knee replacement prosthesis.

The prosthesis may comprise at least part of a knee replacement prosthesis in which the bone engaging element comprises a tibial component and the artificial ligament comprises a replacement anterior cruciate ligament (ACL).

The ligament may be secured within the stem of the bone engaging element via a tensioning element, the tensioning element being at least partially housed within the bone engaging element.

The ligament may be secured within the stem of the bone engaging element via a biasing element, the biasing element being at least partially housed within the bone engaging element.

The ligament may be secured within the stem of the bone engaging element via both a tensioning element and a biasing element, the tensioning element and the biasing element being at least partially housed within the bone engaging element.

According to another aspect, there is provided a prosthesis comprising a bone engaging element and an artificial ligament, an end of the artificial ligament being secured to the body of the bone engaging element, the prosthesis further comprising a ligament support, the ligament support at least partially determining the line of action of the ligament.

The artificial ligament may be secured within a recess formed in the body of the bone engaging element, and the ligament support may comprise a mouth of the recess. The mouth of the recess may be radiused or chamfered.

The ligament support may be shaped like a pulley. For example it may be substantially cotton reel shaped or otherwise formed with a recess or waisted portion. This recess or waisted portion is helpful in centring the artificial ligament and reduces the possibility of dislocation.

The ligament support may project from a surface of the bone engaging element, or may be formed on the retaining element described in previous aspects. Alternatively, the artificial ligament may be secured to the bone engaging element or to the retaining element.

The prosthesis may comprise at least part of a knee replacement prosthesis.

This aspect allows the direction of action of an artificial ligament to be changed, in particular where a biasing element is used to control the stiffness of the assembly. For example, if the biasing element is housed within the tibial stem of a knee replacement prosthesis its line of action must be parallel to that stem. However, the line of action of the ligament must be towards a point of attachment to the femoral component or femur, the position of which changes

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through the range of motion. The use of a ligament support allows for the necessary change in the direction of the line of action of the ligament.

According to another aspect, there is provided a method of implanting a prosthesis comprising first and second bone engaging elements, an artificial ligament and a biasing element, comprising: (a) operatively coupling the biasing element to a first end of the artificial ligament; (b) operatively coupling the biasing element to the first bone engaging element; (c) implanting the first and second bone engaging elements into bone tissue; (d) connecting a second end of the artificial ligament to the second bone engaging element, (e) balancing tension within the artificial ligament.

According to another aspect, there is provided a method of implanting a prosthesis comprising first and second bone engaging elements, an artificial ligament and an adjustable tensioning element operatively coupled to a first end of the artificial ligament and to the first bone engaging element, the method comprising: (a) assembling the first bone engaging element, adjustable tensioning element and artificial ligament; (b) implanting the first and second bone engaging elements into bone tissue; (c) connecting a second end of the artificial ligament to the second bone engaging element; (d) adjusting the position of the adjustable tensioning element until a predetermined tension within the artificial ligament is achieved.

Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

FIG. 1 is a plan view of a bearing component

FIG. 2 is a plan view of an alternative bearing component

FIG. 3 is a plan view of a tibial tray component

FIG. 4 is a perspective view of the tibial tray component of FIG. 3

FIG. 5 is a perspective view of the bearing component and the tibial tray component

FIG. 6 is a perspective view of a partially assembled knee replacement prosthesis

FIG. 7 is a plan view of an embodiment of a tibial component

FIG. 8 is a sectional view along the anterior/posterior centre line XX of the component of FIG. 7.

FIG. 9 is a sectional view along the medial/lateral centre line YY of the lateral compartment of the component of FIG. 7.

FIG. 10 is a sectional view along the medial/lateral centre line ZZ of the medial compartment of the component of FIG. 7.

FIG. 11 is a perspective view of an embodiment of a tibial component

FIG. 12 is a sectional view of another embodiment of a tibial component

FIG. 13 is a sectional view of the component of FIG. 12 in an alternative arrangement

FIG. 14 is a sectional view of an embodiment of a bearing component

FIG. 15 is a perspective view of a knee prosthesis having an artificial ligament.

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FIG. 16 is a partially sectioned side view of a knee prosthesis having an artificial ligament secured via a biasing element.

FIG. 17 is a partial sectional view of the embodiment of FIG. 16.

FIG. 18 is a partially sectioned side view of a knee prosthesis having an artificial ligament secured via a tensioning device.

FIG. 19 is a partial sectional view of the embodiment of FIG. 18.

FIG. 20 is a partial sectional view of a knee prosthesis having an artificial ligament secured via a tensioning device and a biasing device.

FIG. 21 is a partial sectional view of a knee prosthesis having an artificial ligament and a ligament support.

FIG. 22 is a perspective view of a partially assembled knee replacement prosthesis with a modified ligament support. Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

Example embodiments will now be described more fully with reference to the accompanying drawings.

With reference to FIGS. 1 and 2, a bearing component 2 comprises first and second bearing elements 4, 6 and a flexible linking element 8. Bearing component 2 is suitable for use as a meniscal bearing component of a total knee prosthesis, the prosthesis comprising a tibial component, a femoral component and the bearing component 2. Bearing elements 4, 6 of the bearing component are formed of moulded high density polyethylene and each comprise a distal bearing surface (not shown), that is shaped to articulate with a tibial tray, and a proximal bearing surface 10, 12, that is shaped to articulate with an associated condyle of a femoral prosthesis. The proximal bearing surfaces 10, 12 may have any suitable shape appropriate for the chosen femoral component with which the bearing component is to articulate.

The linking element 8 may be a separate cord 14, connected to the bearing elements 4, 6, as illustrated in FIG. 1. The cord 14 may be of any appropriate shape or material. For example, it may comprise a woven flexible fabric or polyester cord. The cord 14 passes through appropriately dimensioned bores 18, 20 that extend across the width of the bearing elements 4, 6 such that ends of the cord 14 extend out of opposite sides of each bearing element 4, 6. A knot 22 is tied in each end of the cord 14 to prevent the cord 14 passing back through the bores 18, 20. The two bearing elements 4, 6 are thus connected together. Relative movement between the bearing elements 4, 6 is possible, as the cord 14 is flexible. In alternative embodiments, the knot 22 may be replaced by a ball or other protruding feature that prevents passage of the ends of the cord back through the bores 18, 20. In another embodiment, as illustrated for example in FIGS. 5 and 6, the cord 14 may be moulded into the bearing elements at the time of manufacture.

In an alternative embodiment, the linking element 8 may be an integral component 16 of the bearing elements 4, 6, as illustrated in FIG. 2. The linking element may for example comprise a thin polyethylene membrane 16 that connects the bearing elements 4, 6 while permitting relative motion there between. The membrane 16 may be moulded into the bearing elements 4, 6 or may be formed during manufacture of the bearing elements by forming the bearing component 2 as a single component and then removing material from

the component so as to define the two bearing elements **4, 6**, leaving only the thin membrane of material **16** connecting the two elements together.

With reference to FIGS. **3** to **6**, a tibial component suitable for use with the bearing component **2** comprises a tray **30** and a bridge element **50**. The bridge element **50** is omitted in FIGS. **3** to **5** for clarity. The tray **30** is formed of a suitable biocompatible metal, such as stainless steel or cobalt chromium molybdenum. The tray comprises a distal surface **32**, which engages a resected tibial bone surface, and may comprise a keel or other stabilising feature (not shown). The tray **30** further comprises a proximal surface **34** that articulates with the distal surfaces of the bearing elements **4, 6** of the bearing component **2**, when the bearing component **2** and tibial component are assembled. The tibial component comprises a lateral compartment **36** and a medial compartment **38**. The lateral and medial compartments may each comprise bearing surfaces **40, 42** with which the bearing elements **4, 6** of the bearing component **2** articulate. The bearing surfaces **40, 42** may be planar, and the articulation may comprise sliding articulation.

With reference particularly to FIG. **6**, the bridge element **50** comprises a beam **52** and two supporting legs **54, 56**. The beam **52** extends substantially parallel to the proximal surface **34** of the tibial tray **30** in an anterior/posterior direction and spans substantially the entire width of the tray **30**. The supporting legs **54, 56** are positioned proximate the anterior and posterior edges of the tray, substantially equidistant of the medial and lateral edges of the tray **30**. The bridge element **50** thus divides the tray **30** into its lateral and medial compartments **36, 38** and defines a passage **60** there between. A proximal surface of the beam **52** may comprise a threaded blind bore and cooperating screw (not shown), suitable for attaching one end of an artificial ligament (not shown) to the bridge element **50**. Alternative means of connecting an artificial ligament may also be used.

The bridge element **50** is formed of any suitable biocompatible metal and may be formed integrally with the tibial tray **30**. Alternatively, the bridge element may be connected to the tray **30** in any appropriate manner. Preferably, the bridge element **50** is removably connected to the tray **30**, facilitating assembly of the final prosthesis. Alternatively, the bridge element **50** may be fixedly connected to the tray **30** at the time of manufacture.

The bearing component **2** and tibial tray **30** may be assembled at the time of manufacture or immediately prior to implantation. When the bearing component **2** and tibial tray **30** are assembled, as illustrated in FIG. **5**, the bearing elements **4, 6** of the bearing component **2** each rest on a respective bearing surface **40, 42** of the tray **30**. The linking element **8** of the bearing component **2** connects the bearing elements **4, 6** together. When the bridge element **50** is assembled with the tray **30** to form the tibial component, as illustrated in FIG. **6**, the linking element **8** of the bearing component extends under the beam **52** of the bridge element, through the passage **60** to connect the bearing element **4, 6**. If the bridge element **50** is integrally formed with the tibial tray **30**, the tray **30**, bridge element **50** and bearing component **2** may be assembled at the time of manufacture. Alternatively, if the bridge element **50** is not integrally formed with the tray **30** but may be connected to the tray after manufacture, then the tray **30**, bridge element **50** and bearing component **2** may be assembled at any time prior to implantation.

In use, the tibial tray **30**, bridge element **50** and bearing component **2** are assembled and implanted by mounting the tibial component onto a resected proximal surface of a tibia.

A femoral component is attached to a distal surface of a femur and the resurfaced joint is assembled. The bearing elements **4, 6** cushion the articulation between the tibial tray and the condyles of the femoral component. The bearing elements **4, 6** are mobile but are retained safely within the joint by the combined action of the linking element **8** and the bridge element **52**. In the event of distraction of the joint in either the lateral or medial compartments, the bearing element in the distracted compartment is held within the joint by its connection to the other bearing element via the linking element **8**. In the event of bilateral distraction, the bearing component **2** is held within the joint space by the bridge **52**. The passage **60** defined by the bridge element **50** is not sufficiently large to allow passage of either of the bearing elements **4, 6**, so dislocation of the bearing component **2** is prevented.

With reference to FIGS. **7** to **11**, a tibial component **100** of a knee prosthesis comprises a distal surface **102**, that is operable to engage a resected surface of a tibia, and a proximal surface **104**, that is operable to engage one or more bearing components (not shown). The component may further comprise a post, keel or other stabilising feature (not shown) that extends from the distal surface and provides stability to the component **100** when implanted. The component comprises a lateral compartment **106**, including a lateral portion of the proximal and distal surfaces **102, 104**, and a medial compartment **108**, including a medial portion of the proximal and distal surfaces **102, 104**. The lateral and medial compartments are separated by a central region **114**.

Each of the lateral and medial compartments comprises a proximal bearing surface **110, 112**. The lateral proximal bearing surface **110** is convex or domed, having a part spherical surface with a radius of curvature R_l . The centre of curvature of the lateral bearing surface **110** is just anterior of the anterior/posterior centre line (X) of the tibial component **100**, and is approximately on the medial/lateral centreline YY of the lateral compartment **106** of the tibial component **100**. The medial proximal bearing surface **112** is concave or dished, having a part spherical surface with a radius of curvature R_m , which is preferably of a similar length to the lateral bearing surface radius of curvature R_l . The centre of curvature of the medial bearing surface **112** is also just anterior of the anterior/posterior centre line XX of the tibial component **100**, and is approximately on the medial/lateral centreline ZZ of the medial compartment **108** of the tibial component **100**.

Kinematic analysis of a patient may be employed to determine the height h_m, h_l of each compartment of the tibial component **100**. Alternatively, the heights h_l, h_m of the lateral and medial compartments may be selected according to the natural positions of the lateral and medial bearing surfaces of the healthy tibia.

With reference to FIGS. **12** and **13**, another embodiment of tibial component **200** comprises a tibial tray **270** and at least three modular surface components **280, 282, 284**. The tibial tray **270** comprises a distal surface **202**, that is operable to engage a resected surface of a tibia, and a proximal surface **204**, that is operable to engage one or more modular surface components. The proximal surface **204** comprises lateral and medial support surfaces **208, 210**, each of which may comprise a connection feature, for example a recess **212**, operable to cooperate with a corresponding connection feature on a corresponding modular surface component, as described below.

The at least three modular surface components comprise a domed lateral surface component **280**, having a convex part spherical proximal bearing surface **210** as described

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above with respect to tibial component **100**, a dished medial surface component **282**, having a concave part spherical proximal bearing surface **212** as described above with respect to tibial component **100**, and a planar medial surface component **284**, having a planar proximal bearing surface **213**. The tibial component **200** may also comprise a lateral planar surface component having a planar proximal bearing surface (not shown). Each modular surface component **280**, **282**, **284** comprises a distal bearing surface that articulates with a corresponding support surface **208**, **210** of the tibial tray **270**. The distal bearing surfaces of the modular surface components **280**, **282**, **284** each comprise a connection feature, for example a lug **290**, operable to cooperate with the corresponding connection feature on the corresponding tibial support surface **208**, **210**.

The tibial component **200** may be provided as a kit of parts comprising a tibial tray **270** and a selection of modular surface components **280**, **282**, **284**, enabling a surgeon to select an appropriate combination of domed, dished and planar bearing surfaces to suit a particular patient.

Both embodiments of tibial component **100**, **200** are operable to be used in combination with appropriately shaped bearings (not shown). The bearings comprise individual medial and lateral bearings, each having a proximal femoral bearing surface that is shaped to articulate with a distal tibial bearing surface that is shaped to articulate with the appropriate one of the lateral or medial bearing surfaces of the tibial component **100**, **200**. A combination of domed lateral and dished medial bearing surfaces on the tibial component **100**, **200** provides increased stability to individual meniscal bearings, and facilitates in recreating the natural motion of the knee.

The tibial components **100**, **200** described with reference to FIGS. 7 to 13, may be used in combination with the bearing component **2** described with reference to FIGS. 1 to 6. A bridge element **50** as described above with respect to FIG. 6 may be mounted in the central region **114** of the tibial component **100**, **200** of FIGS. 7 to 13. If the bearing component **2** is to be used in connection with a tibial component **100**, **200** as described with reference to FIGS. 7 to 13, the distal bearing surfaces of the bearing elements **4**, **6** of the bearing component **2** are shaped to articulate with, for example, the convex and concave bearing surfaces **210**, **212** of the tibial component **200**. An example of a bearing component **102** for use with either of the tibial components **100**, **200** of FIGS. 7 to 13 is illustrated in sectional view in FIG. 14. The bearing component **102** comprises lateral and medial bearing elements **106**, **104**, each of which comprises a proximal bearing surface **110**, **112**, shaped to articulate with an associated femoral condyle. The bearing elements **104**, **106** further comprise distal bearing surfaces **113**, **111**, each of which is shaped to articulate with a corresponding proximal tibial bearing surface **210**, **212**. Thus, the distal bearing surface **113** of the lateral bearing element **106** is part spherical concave, having a radius of curvature substantially equal to the radius of curvature R_l of the lateral bearing surface **210** of the tibial component. Similarly, the distal bearing surface **111** of the medial bearing element **104** is part spherical convex, having a radius of curvature substantially equal to the radius of curvature R_m of the medial bearing surface **212** of the tibial component.

It will be understood by one skilled in the art that any aspect of any of the embodiments described herein may be used in combination with any other aspect of any of the embodiments described herein.

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Referring to FIG. 15, a knee prosthesis **1002** comprises a tibial component **1004** having a tibial tray **1006** integrally formed with a stem **1008**, a femoral component **1010** and a pair of bearing components **1012**, **1013**. The bearing components **1012**, **1013** separate the tibial component **1004** and femoral component **1010**, and are formed with proximal and distal bearing surfaces which engage corresponding bearing surfaces **1014**, **1015**, **1016** on the tibial tray **1006** and on the femoral component **1010**. These various bearing surfaces enable the tibial component **1004** to rotate and translate relative to the femoral component **1010**. The bearing components **1012**, **1013** may be meniscal bearing components, rotational platform bearing components, or fixed bearing components and may be joined bearing components which may be shaped and may articulate in accordance with the embodiments of FIGS. 1 to 14.

FIGS. 16 and 17 illustrate an embodiment of prosthesis **102**, in which an artificial ligament **1118** is connected at one end **1121** to the femoral component **1110**, and at the other end **1123** to a biasing element **1140** mounted in the stem **1108** of the tibial component **1104**. The biasing element **1140** engages the ligament **1118** via a bearing element **1144**. The biasing element **1140** and bearing element **1144** are both received within a bore **1126** formed in the stem **1108**. The bore **1126** opens onto the bearing surface **1114** of the tibial tray **1106** at a mouth **1130**. The mouth **1130** extends partially into the bore **1126** to define an internal annular shoulder **1154** having an annular bearing surface **1156**. The mouth **1130** is smooth, widening to accommodate the artificial ligament **1118** with some play. The mouth may be radiused or chamfered. The artificial ligament **1118** extends into the bore **1126** through a space **1127**, defined between the bearing components **1112**, **1113**, so that the artificial ligament **1118** substantially does not interfere with the bearing components **1112** during normal articulation of the prosthesis.

Any convenient means of connection of the end **1121** of the ligament **1118** to the femoral component **1110** is contemplated. For example, a boss or peg **1119** may be formed on the femoral component for attachment of the ligament **1118**. The end **1121** of the ligament **1118** may be folded over and glued, sewn or otherwise fixed to form a loop (not shown). Alternatively, a hole or eye may be formed in the end **1121** of the ligament **1118**. The artificial ligament may then be secured to the boss **1119** by passing the loop or eye over the boss **1119**. The boss **1119** may have an enlarged head and narrower stem to encourage stable fixation of the ligament once attached to the boss **1119**.

With reference also to FIG. 18, the other end **1123** of the artificial ligament **1118** is attached to the biasing element **1140** via the bearing element **1144**. Any convenient means of connection between the end **1123** of the ligament **1118** and the bearing element **1144** is contemplated. For example, the end **1123** of the ligament **1118** may pass wholly or substantially through the bearing element **1144** and be prevented from passing back through the bearing element **1144** by a stop **1134**. The stop **1134** may take the form of an enlarged body, for example a spherical body (as illustrated in FIG. 16), a cylinder, or any other appropriate form. Alternatively, the stop may comprise a knot **1135** formed in the end **1123** of the ligament **1118** (as illustrated in FIG. 17). In an alternative embodiment (not shown) the end **1123** of the ligament **1118** may be attached directly to the bearing element **1144** without passing through the body of the bearing element **1144**.

The biasing element **1140** comprises a resilient element **1142**. In the illustrated embodiment, the resilient element **1142** is a coiled compression spring **1146** and the bearing

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element 1144 is a plate 1148. However, the resilient element may consist of or comprise any appropriate spring or springs, for example a Belleville washer or an elastic or elastomeric member. An appropriate bearing element may be selected according to the choice of resilient element.

As illustrated particularly in FIG. 18, the spring 1146 and bearing plate 1148 are received within the bore 1126 of the stem 1108. The artificial ligament 1118 extends into the mouth 1130 of the bore 1126, through the coil spring 1146 and through a passage 1150 formed in the bearing plate 1148. A stop 1134 or knot 1136 prevents the ligament 1118 passing back through the passage 1150 as described above. When tensile forces are applied to the ligament 1118, the knot 1135 or stop 1134 bears against an adjacent surface of the plate 1148, forcing an opposite surface of the plate 1148 to engage and compress the spring 1146 against the annular bearing surface 1152 of the shoulder 1150.

The spring 1146 assists in replicating the natural stiffness of the ligament that is to be replaced. The characteristics of the spring are therefore selected to be similar to those of the natural ACL.

Referring to FIGS. 18 and 19, in a further embodiment of prosthesis 1202, an artificial ligament 1218 is connected at one end 1221 to the femoral component 1210, and at the other end 1223 to a tensioning element 1220 mounted in the stem 1208 of the tibial component 1204. The tensioning element 1220 is cylindrical and formed with an external thread 1222 which engages an internal thread 1224 formed in a bore 1226 in the stem 1208.

As in the embodiment of FIGS. 16 and 17, any convenient means of connection of the end 1221 of the ligament 1218 to the femoral component 1210 is contemplated. For example, a boss or peg 1219 may be formed on the femoral component for attachment of the ligament 1218. The end 1221 of the ligament 1218 may be folded over and glued, sewn or otherwise fixed to form a loop (not shown). Alternatively, a hole or eye may be formed in the end 1221 of the ligament 1218. The artificial ligament may then be secured to the boss 1219 by passing the loop or eye over the boss 1219. The boss 1219 may have an enlarged head and narrower stem to encourage stable fixation of the ligament once attached to the boss 1219.

The other end 1223 of the artificial ligament 1218 is attached to the tensioning element 1220. Again, as in the embodiment of FIGS. 16 and 17, any convenient means of connection between the end 1223 of the ligament 1218 and the tensioning element 1220 is contemplated. For example, the end 1223 of the ligament 1218 may pass wholly or substantially through the tensioning element 1220 and be prevented from passing back through the tensioning element 1220 by a stop 1234. The stop 1234 may take the form of an enlarged body, for example a spherical body (as illustrated in FIG. 18), a cylinder, or any other appropriate form. Alternatively, the stop may comprise a knot 1235 formed in the end 1223 of the ligament 1218 (as illustrated in FIG. 19). In an alternative embodiment (not shown) the end 1223 of the ligament 1218 may be attached directly to the tensioning element 1220 without passing through the body of the tensioning element 1220.

The bore 1226 in which the tensioning element 1220 is received opens onto the bearing surface 1214 of the tibial tray 1206 at a mouth 1230. The mouth 1230 is smooth, widening to accommodate the artificial ligament 1218 with some play. The mouth may be radiused or chamfered. The artificial ligament 1218 extends into the bore 1226 through a space 1227, defined between the bearing components 1212, 1213, so that the artificial ligament 1218 substantially

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does not interfere with the bearing components 1212 during normal articulation of the prosthesis. In the case of a monoblock bearing component (not shown) a suitable opening is formed to allow passage of the artificial ligament and to minimise wear or abrasion of the ligament 1218 during movement.

As illustrated in FIG. 19, the tensioning element 1220 may have a substantially spherical recess 1229 in its end 1231 closest to the free end 1228 of the stem 128. A passage 1232 extends from a base of the recess through the tensioning element towards the mouth 1230 in the tibial tray. The passage 1232 is large enough to receive the loop, eye or other fixation feature at the end 1221 of the ligament 1218, but is too small to allow the stop 1234 to pass through. Alternatively, as illustrated in FIG. 20, the tensioning element may simply comprise a passage 1232, the stop or knot 1234, 1235 engaging against a surface 1237 of the tensioning element 1220.

With reference to FIG. 21, a further embodiment of knee prosthesis combines features of the last two embodiments. The prosthesis 1302 comprises a tensioning element 1320, substantially as described with reference to the embodiment of FIGS. 18 and 19, and a biasing element 1340, substantially as described with reference to the embodiment of FIGS. 16 and 17. The biasing element 1340 acts between the ligament 1318 and the tensioning element 1320, as opposed to the shoulder 1350 of the embodiment of FIGS. 16 and 17. The biasing element 1340 comprises a resilient element 1342, which engages the ligament 1318 via a bearing element 1344. In the illustrated embodiment, the resilient element 1342 is a coiled compression spring 1346 and the bearing element 1344 is a plate 1348. However, the resilient element may be any appropriate spring or springs, for example a Belleville washer or an elastic or elastomeric member. An appropriate bearing element may be selected according to the choice of resilient element.

As illustrated in FIG. 21, the spring 1346 and bearing plate 1348 are received within the bore 1326 of the stem 1308 beneath the tensioning element 1320. The artificial ligament 1318 extends through the passage 1332 in the tensioning element, through the coil spring 1346 and through a passage 1350 formed in the bearing plate 1348. A stop 1334 or knot 1336 is formed on the end 1323 of the ligament 1318 as described above. The knot 1335 or stop 1334 prevents the ligament 1318 passing back through the passage 1350. When tensile forces are applied to the ligament 1318, the knot 1335 or stop 1334 bears against an adjacent surface of the plate 1348, forcing an opposite surface of the plate 1348 to engage and compress the spring 1346 against the adjacent surface of the tensioning element 1320.

The spring assists in replicating the natural stiffness of a ligament. The characteristics of the spring are selected accordingly to be similar to those of the natural ACL.

Implantation of the prosthesis of the present invention will be described with reference to the embodiment of FIG. 20. However, it will be understood that corresponding techniques may be employed for all embodiments disclosed herein.

In use of the prosthesis 1302, the femoral component 1310 is implanted into a distal end of a femur (not shown) and the tibial component 1304 is implanted into a proximal end of a tibia (not shown), such that the stem 1308 is located in the intramedullary canal of the tibia, and the tibial tray 1306 rests on the resected proximal end of the tibia. The appropriate bearing component(s) are placed between the femoral component 1310 and the tibial component 1304.

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The artificial ligament **1318**, compression spring **1346** and bearing plate **1348**, tensioning element **1320** and tibial component **1304** are preassembled prior to implantation. The ligament **1318** is connected to the tensioning element **1320** by passing the end **1321** of the ligament **1318** through the passage **1332** via the passage **1350** in the bearing plate **1348** and the spring **1346** and feeding the ligament **1318** through the passage **1332** until the stop **1334** or knot **1335** engages a surface of the bearing plate **1348**. The tensioning element **1320** is then screwed to an appropriate depth into the bore **1326** in the tibial component **1304** to achieve initial tensioning of the ligament **1318** when fully connected.

The femoral and tibial components **1310**, **1304** are then implanted using standard techniques. Once the tibial component **1304** is implanted, the free end **1321** of the ligament **1318** projects through the mouth **1330** in the tibial tray towards the femoral component **1310**. The appropriate bearing components are then placed between the femoral component **1310** and the tibial component **1304** in a known manner.

The end **1121** of the ligament **1118** is then attached to the femoral component **1110** by passing the loop or eye over the boss **1119**.

The joint is then examined to determine whether the tension in the artificial ligament **1318** is balanced with the tension in the retained posterior cruciate ligament (PCL). If the tension in the artificial ligament **1318** is balanced with that in the PCL, the implantation procedure is complete. If the tension in the artificial ligament **1318** is not balanced with that in the PCL, the position of the tensioning element **1320** within the bore **1326** is adjusted, so as to increase or reduce the tension applied to the ligament **1318**. A tool (not shown) may be inserted through the mouth **1330** to engage a drive formation (not shown) formed on the tensioning element **1320**. By rotating the tool, the tensioning element **1320** is rotated and moves axially along the internal thread in the bore **1326**, thereby adjusting the tension in the artificial ligament **1318**.

With reference to FIGS. **17** to **20**, the embodiments of the present invention may further comprise a ligament support **1160** that is operable to change the line of action of the artificial ligament **1118**. The ligament support may comprise a section of or a projection from the mouth **1130** of the bore **1126** in the tibial component **1114**. Alternatively, as shown in FIG. **21**, the ligament support may comprise a lug **1070** that projects from the surface **1014** of the tibial tray **1006**. The lug may be integrally formed with or connected to the tibial tray **1006**.

FIG. **22** shows a knee prosthesis comprising a tibial component **1004** having a tibial tray **1006** integrally formed with a stem **1008**. A pair of bearing components **2012**, **2013** separate the tibial component **1004** from a femoral component (not shown) and are formed with bearing surfaces which engage a corresponding bearing surface **1014** on the tibial tray **1006**. The bearing components **2012**, **2013** are interconnected by a linking element **2008**, as described with reference to the embodiment of FIGS. **1** and **2**. A retaining element in the form of bridge element **2050** is fixed to the tibial tray **1006** to limit the motion of the linking element **2008**. The bridge element **2050** comprises a beam **2052** and two supporting legs **2054**, **2056**. The beam **2052** extends substantially parallel to the proximal surface of the tibial tray **1006** in an anterior-posterior direction and spans substantially the entire width of the tibial tray **1006**. The supporting legs **2054**, **2056** are positioned approximately at the anterior and posterior edges of the tray **1006**, substantially equidistantly at the medial and lateral edges of the tray **1006**. The bridge element **2050** thus divides the tibial tray

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1006 into its lateral and medial compartments and defines a passage **2060** therebetween, which accommodates the linking element **2008**.

An artificial ligament (not shown) is connected to a biasing element (not shown) housed in the stem **1008**. As in previous embodiments incorporating a ligament, the ligament passes out of an opening **1030** in the tibial tray **1006** and abuts a side of the beam **2052** of the bridge element **2050**. It will be appreciated that the engagement of the ligament with the side of the bridge element **2050** causes a deflection of the ligament and a change in the line of action of the ligament. In order to avoid fretting or other wear related damage of the ligament in use, the bridge element **2050** is provided with a recess or chamfer **2051** which helps to locate the ligament, avoids dislocation and provides a smooth surface of engagement between the bridge element **2050** and the ligament. Thus, the bridge element **2050** has the dual function of limiting the motion of the bearing components **2012**, **2013** and acting as a ligament support to change the line of action of the artificial ligament. In alternative embodiments not illustrated, the bridge element **2050** may comprise a pulley or may be provided with a projection or boss to assist in aligning the ligament and preventing dislocation. Furthermore the ligament support surface formed on the bridge element **2050** may be polished or otherwise surface finished to reduce wear of the artificial ligament.

The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the invention, and all such modifications are intended to be included within the scope of the invention.

The invention claimed is:

1. A prosthesis comprising:

a tibial tray including a body defining a bore having a mouth, the bore opening onto a bearing surface extending perpendicular to the mouth;

a femoral component;

an artificial ligament coupled to the tibial tray and the femoral component; and

a ligament support configured to at least partially determine a line of action of the artificial ligament, wherein the ligament support comprises a lug attached to the bearing surface and projecting to a position over the mouth to prevent the artificial ligament from touching the mouth.

2. The prosthesis of claim 1, wherein the artificial ligament is secured within the bore.

3. The prosthesis of claim 1, wherein the mouth of the bore is chamfered.

4. The prosthesis of claim 1, wherein the artificial ligament is secured to a surface of the bore.

5. The prosthesis of claim 1, further comprising an adjustable tensioning element adjustably positionable within the bore and configured to adjust a tension on the artificial ligament.

6. The prosthesis of claim 5, further comprising a biasing element positioned within the bore and configured to provide a biasing force on the artificial ligament.

7. The prosthesis of claim 6, further comprising a bearing element positioned within the bore and adjacent the biasing element and configured to engage an end of the artificial ligament.

8. A prosthesis comprising:

a tibial component having a body that defines a bore
formed into the body, the body further defining a
bearing surface extending perpendicular to the recess;
an artificial ligament configured to be secured within the 5
recess; and
a lug extending from the bearing surface and arranged to
support the artificial ligament, the lug extending from
the bearing surface to a position over the recess to
prevent the artificial ligament from touching a mouth of 10
the recess, wherein the lug at least partially determines
the line of action of the ligament.

9. The prosthesis of claim 8, wherein the mouth of the
recess is chamfered.

10. The prosthesis of claim 8, further compromising a 15
femoral component configured to be secured to the artificial
ligament.

11. The prosthesis of claim 8, further compromising an
adjustable tensioning member adjustably positioned within
the recess and configured to adjust a tension on the artificial 20
ligament.

12. The prosthesis of claim 11, further compromising a
biasing element positioned within the recess and adjacent
the tensioning member.

13. The prosthesis of claim 12, further compromising a 25
bearing element positioned in the bore and adjacent the
biasing member.

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